Turbulent Microstructure Studies in Coastal Ocean Boundary Layers

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LONG-TERM GOALS

My long term goal in this study is to obtain an extensive picture of turbulent mixing processes from near surface to near the bottom boundary layer at dissipation scales in conjunction with measurements of mixing from the injection of a tracer (Ledwell) and in the context of larger scale measurements in the Coastal Mixing and Optics study.

OBJECTIVES

I wish to establish whether the mixing rates inferred from turbulence measurements agree with those determined from the dispersion of a tracer. In the current year the analysis and interpretation of data from the two field experiments in September 1996 and August 1997 were used to explore various methods of forming an ensemble average. This will allow me to make a clearer comparison of vertical diffusivities determined from the two techniques.

APPROACH

I participated in a joint study with Jim Ledwell (WHOI) in two field experiments at the Coastal Mixing and Optics experimental site. Microstructure measurements were obtained using the vertical profiling instrument EPSONDE in repeated profiles from the surface to near the bottom at a time of weak stratification after the passage of a hurricane (1996) and of late summer stronger stratification (1997). The strategy was for Ledwell to inject a tracer on a specific density level and to map the area to obtain the initial conditions for the tracer. This was followed by a microstructure survey along the predicted track of the tracer as it advected with the measured currents. Tracer and microstructure surveys were interspersed over several days to follow the evolution of the dye.

WORK COMPLETED

The measurement of microstructure profiles, interspersed with dye injection and dispersion measurements were completed for four depths and density gradients from two field programs in 1996 and 1997 done near the Coastal Mixing and Optics mooring site in about 70 meters of water. Two dye-microstructure studies completed by Ledwell and Oakey in the fall of 1996 were with rhodamine at mid-depth and fluorescein at about 50 meters. In 1997 injections were done at about 20 meters from the surface with rhodamine and at about 5 meters above bottom with fluorescein near the central mooring site of the Coastal Mixing and Optics experiment in water depth of about 70 meters. In excess of 2000 microstructure profiles have been analyzed and edited to obtain estimates of dissipation, ε , and temperature variance, χ_θ, and derived vertical diffusivities for each profile segmented in bins of about 1.8 meters from commonly used microstructure models. Estimates of vertical diffiusivity from microstructure data have been compared to those obtained from Ledwell's dye dispersion data. These results have been presented at meetings and papers are in preparation for publication.

RESULTS

Microstructure data from all four dye-microstructure experiments have been analyzed and edited to provide estimated of the rate of turbulent mixing to compare with the estimates of mixing from the spreading of a tracer. As an example of the results, data from dye injection 2 (1996) at a depth of 45 meters ($\sigma_\theta = 24.3$) will be shown. In Figure 1, events in the dye experiment are indicated by triangles, including the dye injection and three surveys. Three sets of microstructure data were collected along three lines. The solid line indicates the path of the center of the tracer patch projected between the surveys using hourly ADCP velocities. This line extends beyond Survey 3 to the time of the last EPSONDE survey. Shaded ellipses indicate the 4σ extent of the tracer patch in the zonal and meridional directions (Sundermeyer, 1998). The CMO mooring sites are indicated by the filled circles.

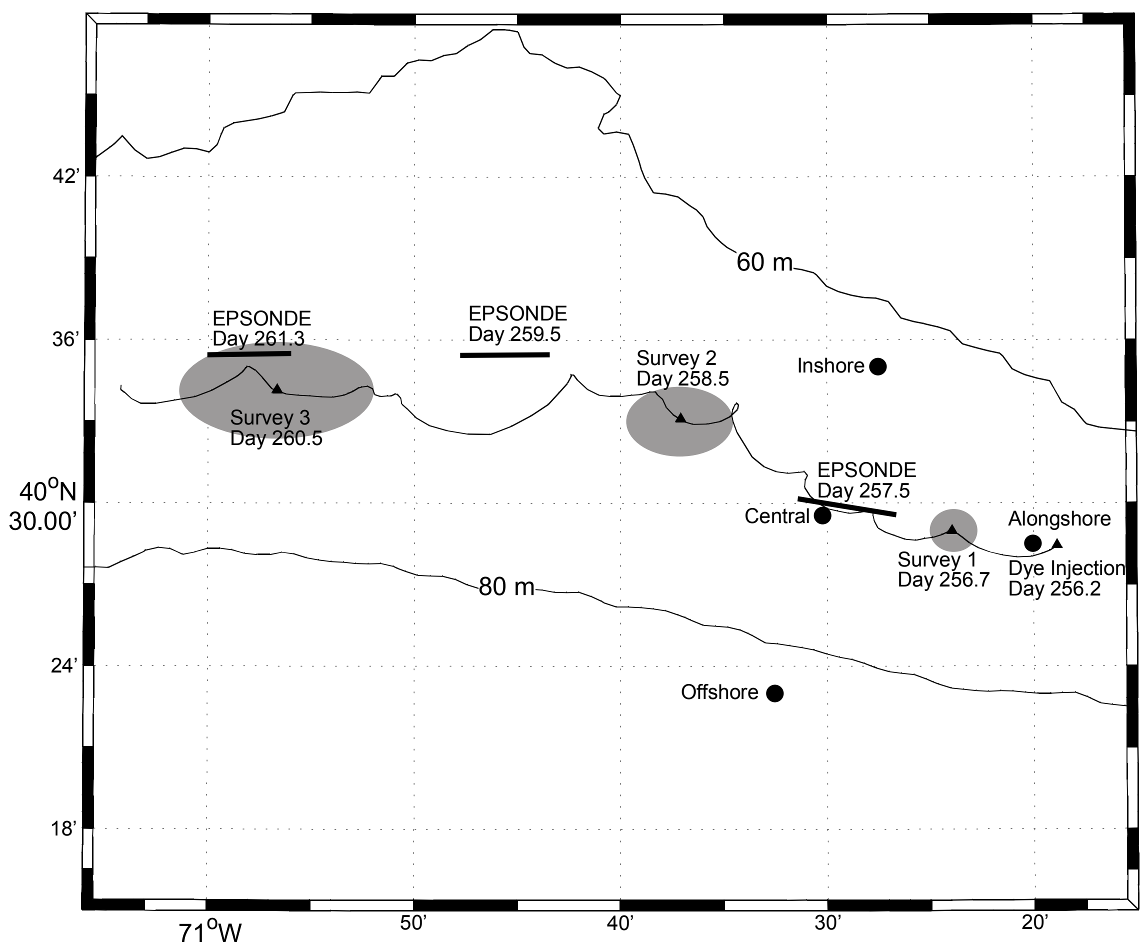

Figure 1: Microstructure and tracer measurements for the second dye injection in 1996.

The microstructure data were obtained in bursts of typically 20 to 30 profiles by successively dropping the instrument EPSONDE along a line of about 5-km as the ship steamed at about 2 knots. These data were averaged into profiles giving mean values and standard deviation for each burst for dissipation, ε, and temperature variance, χ_θ, as well as depth, density and vertical diffusivities. The diffusivities that matched the density surface of the tracer were found and used in integrating diffusivity to compare to the tracer. Mean density profiles are shown in Figure 2 to indicate the depth ranges over which data were selected.

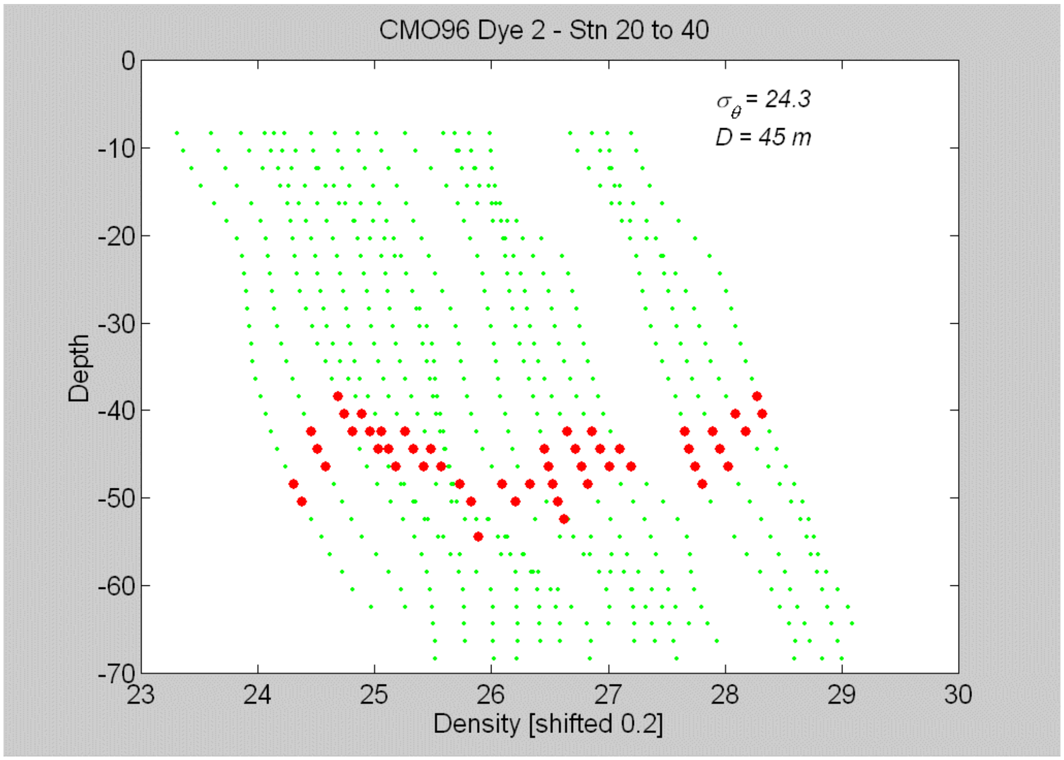

Figure 2: Waterfall plot of mean density profiles for dye injection 2 (1996) measured by EPSONDE where the sections of the profile indicated in red dots are used to calculate a diffusivity to compare to that determined by the dye. Each profile represents the average of 15 to 40 individual drops.

The diffusivity profile around the target isopycnal, determined from these burst averaged station data, is shown in Figure 3. The results of two methods of ensemble averaging are displayed in this Figure. The first method, "station" (blue line), determines a mean dissipation of temperature variance for the whole survey and, subsequently, uses this with an estimate of the mean temperature gradient over that period to calculate diffusivity. The second method, "segment" (yellow line), calculates diffusivity for each segment of data obtained during the survey and then uses these values to obtain a mean for the survey. The diffusivity determined for the temperature gradient microstructure K_T (top panel) is in good agreement with the estimate from the dye (green) for the "segment" average. For the "station" average, the lower limit of the dye estimate overlaps the upper limit of the microstructure data. Diffusivity obtained from the dissipation (bottom panel), assuming a mixing efficiency of 0.25, is larger than K_T and suggests that a lower value of mixing efficiency is appropriate.

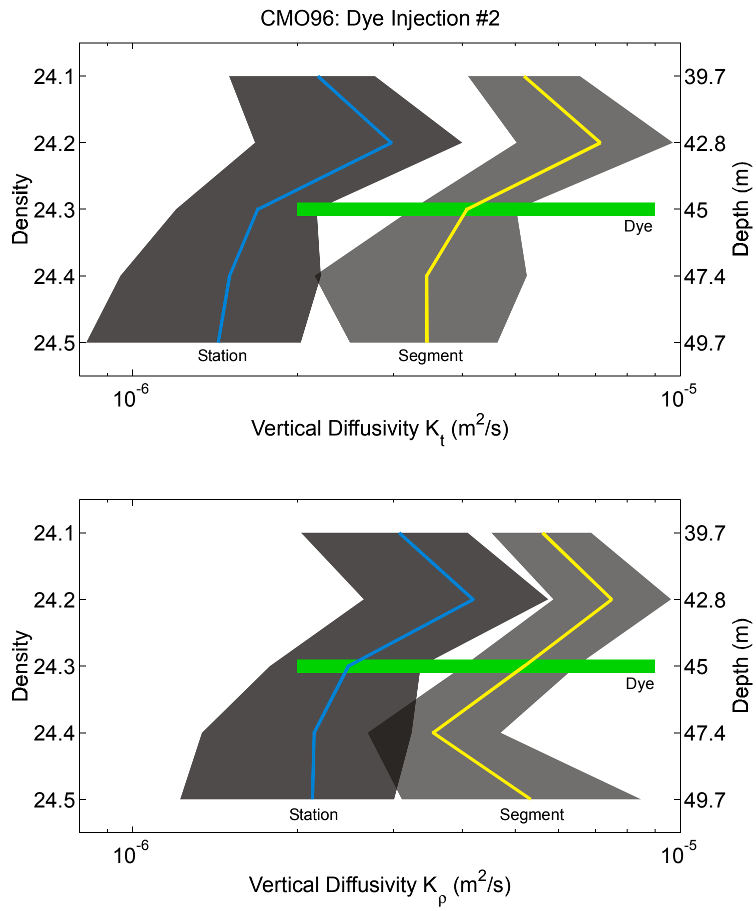

Figure 3: Vertical diffusivity determined for the temperature gradient microstructure K_T (top panel) and that obtained from the dissipation, K_ρ, assuming a mixing efficiency of 0.25 (bottom panel). The range of the diffusivity for the dye and its depth and density is indicated by the green line.

IMPACT/APPLICATIONS

This is the first time that tracer and microstructure measurements of mixing in the ocean have been done on the same length and time scales to test commonly used mixing models.

TRANSITIONS

RELATED PROJECTS

This study is part of the Coastal Mixing and Optics experiment in particular the turbulence results are being compared to those obtained by Jim Ledwell of WHOI.

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